REMARKS

The present invention is a device, as illustrated in Figs. 1 and 2, for coupling ultrasonic waves into a solid body 12 as identified in the requested Authorization to Amend the Figs. 1 and 2. The solid body 12 may be biological tissue. At least one ultrasonic transducer unit 6 couples ultrasonic waves into the solid body via a gaseous coupling medium 9 provided between at least one ultrasonic wave generating unit and a boundary surface 8. The ultrasonic waves generated by the at least one ultrasonic transducer are directed into the closed volume 1 which is provided with at least a first opening 3 and a second opening 4. A flow of gas 13 provides an overpressure inside the closed volume which is directed into an interior of the volume through the first opening and exits the closed volume through the second opening which directly faces the boundary surface.

The specification stands objected to regarding an informality. The specification has been amended to correct the informality and to improve its form for reexamination.

Claims 1-13 stand objected to and rejected under 35 U.S.C. §112, second paragraph, as being indefinite. Newly submitted claims 14-42 have been drafted to overcome the stated grounds of objection and rejection.

Claims 1-13 stand rejected under 35 U.S.C. §102 as being anticipated by United States Patent 4,378,699 (Wickramasinghe). This ground of rejection is traversed for the following reasons. Wickramasinghe discloses a scanning acoustic microscope which scans targets located within a housing into which a source of compressed air is introduced. The scanning acoustic microscope is fundamentally different than the subject matter of claim 14 and the dependent claims. Specifically, claim 14, *inter alia*, recites a device for coupling ultrasonic waves into a solid body to

be probed via a boundary surface located outside a closed body. Wickramasinghe discloses only the scanning of the object located within a housing. Accordingly, Wickramasinghe does not anticipate newly submitted claims 14-42. Furthermore, there is no basis why a person of ordinary skill in the art would be motivated to modify the teachings of Wickramasinghe to arrive at the subject matter of newly submitted claims 14-42.

Claims 6-9 stand rejected under 35 U.S.C. §103 as being unpatentable over Wickramasinghe in view of United States Patent 4,787,407 (Vogel). This ground of rejection is traversed for the following reasons. Vogel pertains to a method and apparatus for detecting a fluid level in a tank. Accordingly, Vogel does not disclose a device for coupling ultrasonic waves into a solid body to be probed via a boundary surface located outside a closed body.

If the proposed combination of Wickramasinghe and Vogel were made, the subject matter of the present invention would not be achieved for the reason that there is no teaching in either Wickramasinghe or Vogel of a device of coupling ultrasonic waves into a solid body to be ultrasonically probed. Moreover, there is no basis why a person of ordinary skill in the art would be led to combine the teachings of a scanning acoustic microscope and a method and apparatus for detection of fluid level in a tank except by impermissible hindsight.

Dorr, which has not been applied in the rejection, pertains to an ultrasonic distance measuring device and therefore, does not disclose a device for coupling ultrasonic waves into a solid body to be ultrasonically probed via a boundary surface located outside a closed body.

Submitted herewith is a Request for Authorization to Amend the Drawings to include reference numerals 12 and 13 which respectively identify the solid body

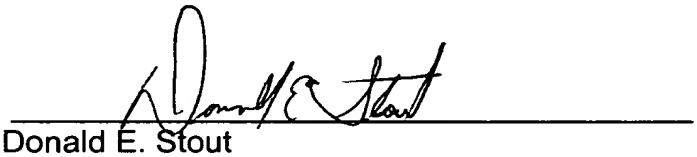
which is probed and compressed air being introduced into the enclosure 1. The specification has been amended consistent with the addition of reference numerals 12 and 13. The addition of reference numeral 12 and the amendment to the specification addresses the issue raised by the Examiner with respect to claim 12 as to what the solid body is.

In view of the foregoing amendments and remarks, it is submitted that each of the claims in the application is in condition for allowance. Accordingly, early allowance thereof is respectfully requested.

Please charge any shortage in fees due in connection with the filing of this paper, or credit any overpayment of fees, to the deposit account of Antonelli, Terry, Stout & Kraus, LLP, Deposit Account No. 01-2135 (785.39987X00).

Respectfully submitted,

ANTONELLI, TERRY, STOUT & KRAUS, LLP



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Attachment

DES:dlh

Device for Coupling Ultrasonic Waves into a Medium

Technical Field

The present invention relates to a device for coupling ultrasonic waves into a medium via a boundary surface, having at least one ultrasonic transducer unit, which couples the ultrasonic waves into the medium via a coupling medium provided between the ultrasonic-wave-generating unit and the boundary surface.

State of the Art

Devices of the aforementioned type are employed for non-destructive examination of materials and, moreover, find widespread use in medicine for diagnosing inside the human body, for example physical examinations during pregnancy.

The interaction of ultrasound and preferably solid bodies is based, similar to light in glass, on absorption (weakening), reflection and refraction. Reflection and refraction occur at the boundary surface between two substances of different physical properties, e.g. at a boundary surface of a body. As these differences are often small, in particular in the case of composite materials, high sensitivity of the receiver device is a prerequisite by means of which the backreflected ultrasonic waves can be detected. Frequently ultrasound emitters and ultrasound receivers are integrated in one unit and are known as ultrasonic transducer systems. In order to be able to use an ultrasonic transducer both as an emitter and as a receiver, ultrasonic waves are emitted in short intervals and the reflected ultrasound is received in the pauses.

Description of the Invention

The object of the present invention is to improve a device for coupling ultrasonic waves into a medium via a boundary surface, having at least one ultrasonic transducer unit which couples ultrasonic waves into the medium via a coupling

medium provided between the ultrasonic-wave generating unit and the boundary surface in such a manner that the degree of coupling ~~in, that is the degree~~ with which the ultrasound is coupled into the medium, is distinctly raised. Moreover, the object is also to achieve close coupling between the ultrasonic waves generating unit and the ~~to be examined~~ medium for better detection of the ultrasonic waves reflected at the medium.

The solution to the object forming the basis of the present invention is set forth in claim 1. Advantageous further improvements are described in the subject matter of the subclaims as well as in the specification and in the preferred embodiments.

With air-coupled excitation of the ultrasonic waves, in which the air is utilized as the coupling medium, according to the present invention, a ~~so-called~~ compressed air sliding shoe, ~~a device which will be described in the following,~~ is employed to decisively improve energy balance.

Air-coupled excitation of ultrasonic waves refers to the ultrasonic transducer unit generating ultrasonic waves in the air, with these ultrasonic waves ~~hitting~~ striking the boundary surface ~~respectively~~ of a solid body surface at a suited angle after passing through a ~~more or less~~ long path and excite indirect waves (so-called density waves or shear waves or surface waves) running along the surface of the solid body (so-called Rayleigh waves or creeping waves) in the medium ~~respectively~~ in a solid body. In this way, various plate-wave modes can be excited even at plate-shaped materials.

The invented device of the invention according to the generic part of claim 1, is distinguished by the fact that the has ultrasonic waves generated by the ultrasonic transducer unit, which are directed into a closed volume provided with at least a first opening and a second opening, that A a flow of gas, which ensures that there is an overpressure inside the closed volume and simultaneously represents the coupling medium, is directed into the interior of the volume through the first opening, and that the second opening, through which the flow of gas coming from the volume exits, faces the boundary surface directly.

Preferably compressed air is introduced as the coupling medium into the interior of the closed volume, which is enclosed in a housing. The compressed air flows out through at least one opening on the side of the housing facing the boundary surface. Due to the selective outflow of the compressed air at the underside of the housing of the so-called compressed-air sliding shoe, the sliding shoe is actually sucked to the boundary surface due to the so-called compressed hydrodynamic paradox, thereby yielding very close coupling between the housing and the boundary surface. This again results in a, for the most part, constant distance between the device and the boundary surface thereby improving measuring conditions considerably.

As an alternative to the hydrodynamic paradox effect, the intensity of the gas flow can be raised further in such a manner that a kind of air cushion is formed between the device and the boundary surface so that the entire device hovers over the boundary surface like a kind of hovercraft.

The main advantage of the closed volume, to which compressed-air is applied, inside the compressed-air sliding shoe, is that due to the pressure-dependent higher air density inside the housing, the ultrasonic waves can couple more effectively into the medium, which is preferably a solid body, via the boundary surface. Usually the pressure inside the compressed-air sliding shoe is approximately 10 times higher than in the surroundings. Thus, the ultrasonic waves can be coupled into the medium 10 times better.

The purpose of the invented device ~~is~~ coupling ~~in~~ ultrasonic waves preferably at those technical surfaces which, due to cleaning conditions or similar circumstances, cannot be directly contacted with a probe. With the ~~invented~~ device, ultrasonic waves can be coupled in highly effectively ~~via~~ the boundary surface without ~~touching it~~ and without very complicated technology regarding sealing measures connected with maintaining the air pressure inside the housing ~~respectively~~ inside the compressed-air sliding shoe because the pressure conditions set in automatically as a result of the ~~so-called~~ hydrodynamic paradox.

For further details, reference is made to the following preferred embodiments.

Brief Description of the ~~Invention~~ DRAWINGS Drawings

The present invention is made more apparent in the following ~~using~~ preferred embodiments described with reference to the accompanying drawings by way of example without the intention of limiting the scope or spirit of the inventive idea. Depicted is in:

Fig. 1 is a cross section of an advantageous embodiment

Fig. 2 is a cross section of an advantageous alternative embodiment.

Description of the Preferred Embodiments

Ways of Carrying Out the Invention, Commercial Applicability

In the simplest form of a preferred embodiment (see ~~figure~~ Fig. 1), ~~the~~ compressed air 13 flows into the closed volume 1, which is enclosed by a housing 2. The housing 2 is provided with two openings 3, 4. The compressed air flows into the interior of the housing 2 through opening 3 through a compressed-air line 5 attached thereto. The compressed-air escapes to the outside through the other opening 4. An ultrasonic transducer unit 6, preferably placed on the side facing opening 4, is provided inside the housing 2 in such a manner that the ultrasonic waves from the transducer are ~~can be released~~ directed ~~at~~ toward the opening 4. In this case, opening 4 also acts as a ~~sound-exit~~ opening through which sound exits.

Preferably, delay-time-controlled stack transducers ~~can be~~ are used as ultrasonic transducer units. Conventional transducers can also be built into the compressed-air sliding shoe. In particular for low frequency applications, the individual plates of the stack transducers can be excited in phase. Conventional single oscillator transducers can, of course, also be ~~built in~~ used.

The compressed-air flow 9 ~~developing~~ flowing radially between the underside 7 of the housing and the ~~probe~~ surface ~~respectively boundary~~ surface of the solid body is being probed with ultrasonic waves from a 8 which generates a vacuum between the two surfaces which draws the compressed-air sliding shoe to the ~~probe~~

surface 8. The diminishing distance between the underside of the sliding shoe and the probe surface 8 raises flow velocity, which ~~for its part leads to~~ causes an increased contact force. Equilibrium sets in when the force of attraction generated by the radial flow equals the force of repulsion (caused by the pressure building up inside the sliding shoe). The width of the air gap between the underside of the sliding shoe and the probe surface and the amount of pressure inside the sliding shoe depends on the geometric design.

However, the described simplest version of the compressed sliding shoe has certain drawbacks which are caused by gas-flow turbulences inside the housing 2 [: therefore,] which in particular, causing the occurrence of disturbing fluctuations in the shape and the amplitude of the ultrasonic pulses inside the housing 2. In order to reduce these disturbances, ~~suited~~ sound-conducting means 10 are built into the interior of the housing 2 in order to deflect and/or concentrate the ultrasonic waves [accordingly and/or to concentrate, for example on] toward the sound-exit opening 4. The purpose of the sound-conducting means 10 is, in particular, to separate the spatial zone ~~passed by~~ through which the ultrasonic waves pass and a spatial zone in which the gas flow is introduced into the housing [can develop freely]. In ~~figure~~ Fig. 2, a funnel insert, which concentrates the ultrasonic waves coming from the ultrasonic transducer unit in the direction of the sound-exit opening 4, is provided as the sounding-conducting means 10.
The interaction volume between the turbulent compressed air and sound is therefore very much limited which reduces turbulent effects accordingly. Fundamentally instead of a funnel, all built-in elements such as baffle plates, hole filters etc. can be used which contribute to a laminating or calming the air flow. Of course, any other gas (e.g. CO_2) can be employed instead of compressed air.

Moreover, the sound-exit opening and other compressed-air openings can be disposed on the housing separated from each other.

Depending on the application, the ultrasonic transducer unit 6 can be built into the housing perpendicular to the ~~probe~~ surface 8 or slanted to generate oblique ultrasonic waves. If transmission and reception are realized with two ultrasonic

transducers, they can be built into separate sliding shoes or into a common sliding shoe. In the latter case, the two transducers can have separate sound-exit openings with separate baffles for suppressing turbulences or common sound-exit openings with a common baffle for suppressing turbulences. The geometric arrangement (slanted position, spacing) is adapted depending on the application (testing thick components or thin components, exciting spatial waves, surface waves or plate waves).

List of Reference Numbers

1 closed volume

2 housing

3,4 openings

5 compressed-air line

6 ultrasonic transducer unit

7 underside

8 boundary surface, probe surface

9 compressed-air flow

10 sound-conducting means

N w Claim 1:

14 1. A device for coupling in ultrasonic waves into a [medium] solid body via a boundary surface, ~~having~~ at least one ultrasonic-wave transducer unit, which couples ultrasonic waves into ~~said~~ [medium] solid body via a gaseous coupling medium provided between the ultrasonic-wave-generating unit and ~~said~~ boundary surface, **wherein** the ultrasonic waves generated by ~~said~~ ultrasonic transducer unit ~~being~~ directed into ~~a~~ closed volume, which is provided with at least a first opening and a second opening, a flow of gas, ~~which ensures~~ an overpressure inside ~~said~~ closed volume [~~and simultaneously represents said coupling medium~~] ~~being~~ directed into ~~said~~ volume through ~~said~~ first opening, and ~~said flow of gas~~ exits ~~said~~ closed volume through ~~said~~ second opening directly facing ~~said~~ boundary surface.

What Is Claimed Is:

1. A device for coupling in ultrasonic waves into a medium via a boundary surface, having at least one ultrasonic-wave transducer unit, which couples ultrasonic waves into said medium via a coupling medium provided between the ultrasonic-wave-generating unit and said boundary surface,
wherein the ultrasonic waves generated by said ultrasonic transducer unit being directed into a closed volume, which is provided with at least a first opening and a second opening,
a flow of gas, which ensures an overpressure inside said closed volume and simultaneously represents said coupling medium, being directed into the interior of said volume through said first opening, and
said second opening, through which a flow of gas coming from inside said volume exits, directly facing said boundary surface.

2. The device according to claim 1,
wherein ~~said~~ closed volume ~~being~~ bordered by a housing in which ~~said~~ ultrasonic transducer is insertable or integrated in ~~such~~ a manner ~~that~~ the ultrasonic waves ~~are~~ directed at ~~said~~ opening directly facing ~~said~~ boundary surface.

3. The device according to claim ~~1 or 2~~,
wherein ~~said~~ flow of gas ~~being~~ air, preferably compressed air.

4. The device according to ~~one of the~~ claims ~~1 to 3~~,
~~wherein~~ a compressed-air line ~~being~~ connected to ~~said~~ first opening.

5. The device according to ~~one~~ of the claims ~~2 to 4~~,
wherein ~~said~~ housing ~~having~~ a surface, ~~which~~ is provided with at least ~~said~~ second opening facing ~~said~~ boundary surface.

6. The device according to claim 5,
wherein said housing in which said surface facing said boundary surface being provided with a third opening at which the ultrasonic waves are directed by corresponding alignment of said ultrasonic transducer unit.

7. The device according to ~~one of the~~ claims ~~1 to~~ 6,
wherein sound-conducting means for ~~deflecting and/or concentrating~~ ultrasonic waves ~~being provided~~ inside ~~said~~ closed volume.

8. The device according to claim 7,
wherein said sound-conducting means ~~being plane~~ elements, ~~such as baffle plates~~, ~~which~~ separate a first spatial zone inside ~~said~~ closed volume, in which ultrasonic waves can propagate ~~for the most part~~ without the interference by gas flows, and a second spatial zone in which ~~said~~ gas flow is directed.

9. The device according to claim ~~7 or 8~~,
wherein a ~~funnel-shaped sound-conducting means being provided~~ which leads ~~said~~ ultrasonic waves from ~~said~~ ultrasonic transducer to an opening ~~in such a manner that said ultrasonic waves pass through said opening as unimpeded as possible by the gas flow~~.

10. The device according ~~to one of the~~ claims ~~5 to~~ 9,
wherein ~~said~~ flow of gas passing through ~~said~~ opening facing ~~said~~ boundary surface flowing between ~~the~~ upper side of ~~said~~ housing facing ~~said~~ boundary surface and ~~said~~ boundary surface ~~flowing~~ radially in relation to ~~said~~ opening to ~~the~~ outside, ~~with~~ an vacuum ~~developing which draws said~~ housing toward ~~said~~ boundary surface to ~~such a degree until a kind of~~ gas cushion is ~~created having~~ a thickness at which the forces of attraction ~~being~~ created by ~~said~~ vacuum and ~~the immanent~~ forces of repulsion present due to the mass impulse of the flow of gas between ~~said~~ housing and ~~said~~ boundary surface are in equilibrium.

11. The device according to ~~one of the~~ claims ~~1 to 10~~, **wherein** ~~two ultrasonic transducers, preferably~~ a transmitter transducer and a receiver transducer ~~being provided~~.

12. The device according to one of the claims 1 to 11, **wherein** ~~said~~ medium into which the ultrasonic waves couple in being a solid body.

13. The device according to ~~one of the~~ claims ~~1 to 12~~, **wherein** ~~said medium~~ into which the ultrasonic waves couple ~~in being~~ biological tissue.

Abstract

~~Disclosed is a~~ device for coupling in ultrasonic waves into a medium via a boundary surface, ~~having~~ at least one ultrasonic-wave transducer unit, which couples ultrasonic waves into the medium via a coupling medium provided between the ultrasonic-wave-generating unit and the boundary surface.

~~The invention is distinguished by~~ the ultrasonic waves generated by the ultrasonic transducer unit ~~being~~ directed into a closed volume, which is provided with at least a first opening and a second opening, a flow of gas, ~~which~~ ensures an overpressure inside the closed volume and simultaneously ~~represents~~ the coupling medium, ~~being~~ directed into the interior of ~~said~~ volume through the first opening, and ~~the second opening, through which a flow of gas coming from inside said volume~~ exits, directly ~~facing~~ the boundary surface.